PREDICTIVE MODELLING OF MARINE FISH LANDINGS OF MAHARASHTRA COAST

Dissertation submitted in partial fulfillment of the requirements for the degree of

M.F.Sc. (FISHERIES RESOURCE MANAGEMENT)

by

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Dedicated to my Dearest
Pappa , Mummy and Grisha

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Dated: 2nd JULY, 2002.

CERTIFICATE

Certified that the thesis entitled **"PREDICTIVE MODELLING ON MARINE FISH LANDINGS OF MAHARASHTRA COAST"** is a record of independent bonafide research work carried out by **Mr Grinson George** during the period of study from September 2001 to February 2002 under our supervision and guidance for the degree of **Master of Fisheries Science (Fisheries Resource Management)** and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

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I here by declare that the dissertation entitled **"PREDICTIVE MODELLING OF MARINE FISH LANDINGS OF MAHARASHTRA COAST"** is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associateship, fellowship or any other similar title.

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सारांश

मत्स्य अवतरण संबंधी जानकारी के लिए मछली की पकड़ प्रवृति विश्लेषात्मक तथा स्टॉक मूल्यांकन, प्रबंधीय प्रणाली में दीर्घकालीन उत्पादन प्राप्त करने के लिए वर्षों से यह एक महत्वपूर्ण सुझाव रहा । वर्तमान में महाराष्ट्र का वार्षिक समुद्रीय मत्स्य अवतरण 3.9 लाख टन है । राज्यों के क्रम में महाराष्ट्र समुद्री मत्स्य उत्पादन में तीसरे स्थान पर है जबकि गुजरात व केरल उसके ही बाद क्रम में आते है । 80 में मिश्रित बढ़त दर 3.8% रहा जबकि 90 में 2.6% रहा । 1996 में 4.52 लाख टन होते हुए भी पिछले तीन वर्षों से मत्स्य अवतरण के उत्पादन पद्धति में एक महत्वपूर्ण बदलाव देखा गया । त्रैमासिक कैंच द्वारा 1975-1999 की अवधि में महाराष्ट्र तट में मत्स्य अवतरण के पूर्वानुमान के लिए एक अनुकूल ऑटो रिग्रैसिव इंटीग्रेटेड मुविंग एवरेज (ARIMA) मॉडल का विकास किया गया । आम मौसम व मौसमीय मछलियों की पहचान के लिए ऑटो सहसम्बन्ध तथा अर्ध ऑटो सहसम्बन्ध का प्रयोग किया गया । मॉडल के ऑर्डर के लिए एकाईके इन्फरमेंशन क्रैयटेरियन (AIC) तथा सिवारस बॉयसिल इन्फरमेंशन कैयटेरियन का प्रयोग किया गया ।

मॉडल मापदण्ड के अनुमान के लिए एस.पी.एस.एस.सॉफ्टवेयर में ट्रून्डस मॉडयूल एलगोरिथम का प्रयोग किया गया । अगले दो सालों के लिए त्रैमासिक आधार पर व कॉन्फिडेंस लिमिट्स के साथ फिटेड मॉडल का प्रयोग किया गया है । मॉडल जिन्हें पहचाना गया वे इस प्रकार है -

ए.आर.आई.एम.ए.(0,0,0) (0,1,1) के कुल अवतरण हेतु
ए.आर.आई.एम.ए.(0,1,1) (2,1,3) बॉम्बे डक के हेतु
ए.आर.आई.एम.ए.(2,1,3) (2,1,1) माइक्रल हेतु
ए.आर.आई.एम.ए.(0,1,1) (0,1,4) नॉन पिनियडस हेतु
ए.आर.आई.एम.ए.(0,1,1) (0,1,1) कैटफिश हेतु
ए.आर.आई.एम.ए.(0,1,1) (2,1,1) कैटानजिड के अवतरण हेतु आदि । ची स्क्वयर टेस्ट यह दर्शाते है कि फिटेड मॉडल डाटा स्पष्ट करने के लिए पर्याप्त है ।

Stud-sara2002

ABSTRACT

Information on fish landings over a period of time, catch composition, trend analysis and stock assessment are essential for suggesting management strategies to achieve sustainable production over the years. Annual marine fish landing of Maharashtra are placed presently at 3.9 lakh tonnes. The state ranks third among the Indian states in marine fish production next only to Gujarat and Kerala. Annual landings during eighties (1980-1989) and nineties (1990-1999) were analyzed for estimation of compound growth rates. The quarterly total landings and landings of five species viz, Bombay duck, carangids, Cat fishes, Mackerel and non penaeid prawns during 1975-1999 were used for fitting Auto Regressive Integrated Moving Average (ARIMA) models. Annual compound growth rates for 1980-1989 and 1990-1999 for total marine fish landings were of 3.8 percent and 2.6 percent respectively. Mackerel landings showed significantly high growth rate of about 90% and 12% during eighties and nineties respectively. Auto correlation and partial auto correlation were worked out for identifying the seasonality or otherwise of the time series data. Akaike Information Criterion (AIC) and Schewatz Bayesean information Criterion were used for the estimation of the order of the model. An algorithm using "trends" module in SPSS software was used for estimation of model parameters. The models identified in the present study are ARIMA (0,0,0)(0,1,1) for total landings, ARIMA (0,1,1)(2,1,3) for Bombay duck, ARIMA (0,1,1)(2,1,1) for carangid landings, ARIMA (0,1,1)(0,1,1) for catfish, ARIMA (2,1,3)(2,1,1) for Mackerel, and ARIMA (0,1,1)(0,1,4) for non-penaeid prawns. T-values showed that the fitted models are adequate to explain the data. Fitted models were used to forecast landings for the next two years on quarterly basis of total landings and also the landings of five species under study.

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Introduction

1. INTRODUCTION

Fisheries sector has been recognized as a powerful income and employment generator as it simulates growth of a number of subsidiary industries and is a source of cheap animal protein. It is an instrument of livelihood for a large section of economically backward population of the country. About 7 million people directly or indirectly depend on the fisheries sector. During 2000-2001, the volume of seafood exported was 4.41 lakh tones worth RS.6400 crores. During 1998-99, fisheries sector contributed Rs. 22,223 crores to the total Gross domestic Product (GDP), forming 1.4% of the total and $.73% of the GDP from Agriculture.

India has an estimated fish production potential of 8.40 million tonnes, with 3.9 million tonnes expected from marine fisheries. As against the said potential, the country is producing 5.66 million tonnes (during 2000-2001) with a contribution of about 50% each from marine and inland fisheries. Based on the total fish production, India occupies third position in the world contributing little over 4% to the world production. In the case of inland fish production, our country ranks second in the world and occupies an important place in Asian aquaculture. The current per capita availability of fish per annum works out about 10 kg for the fish eating population of the country, which is less than minimum recommended requirement of 11kg spelt out by the World Health Organisation.

The structure of fish production in the country has undergone drastic changes. In 1950-51, the share of marine fisheries was 71% of the total fish production of 7.52 lakh tonnes. During seventies and eighties, the share of inland fisheries was just above one third of the total fish production and gradually increased to reach 40% in 1990-91 and 5% in 2000-2001. The changes were due to deceleration in growth of marine fish production and a policy shift in favor of inland fisheries, especially aquaculture. The share of culture fisheries (aquaculture) in inland fisheries has shown tremendous increase during the last few years and rose to 43% in 1984-85 to about 80% in 1999-2000.

Various measures are being undertaken to optimize and rationalize the fishing fleet. Area wise deployment of different categories of fishing vessels, regulation of fishing, gear and mesh size, uniform closed fishing season, development of deep sea fishing including diversified fishing, replenishment of fish stocks by undertaking projects on sea ranching, setting up of artificial reefs and the like are proposed, for increasing fish production.

Maharashtra, the third largest among the marine fish producers in India with 526104 tonnes in 2000-2001 is located along the Northwest coast of India between 16^0tto 22^0 N latitude and 72^0 to 76^0 to 78^0 and 9^1 longitudes (figure 1). Marine fisheries contributed about 77% to the total fish production of the state. The lush greenery of the Western Ghats occupies the western strip parallel to the roaring froths of Arabian Sea. Konkani culture prevailing in the five maritime districts of Maharashtra viz., Thane, Greater Mumbai, Raigad, Ratnagiri and Sindhudurg is unique from other areas of the state. They occupy the productive coastline of 720 km with a continental shelf area of 1,11,512 km.

Adjoining the seashores are marshy lands with pneumatophore bed of Mangrove vegetation with an estimated area of 80,000 ha. Virgin saline soils with a potential of 14,550 ha have been found suitable for brackishwater fish/ prawn culture. Heavy urbanization of this fastest developing industrial state is lamented as an ecological threat faced by the bio-resource diversified systems. Though engaged in a variety of seasonal, full and unemployed conditions the traditional fishermen communities still earn their livelihood by fishing as their main vocation.

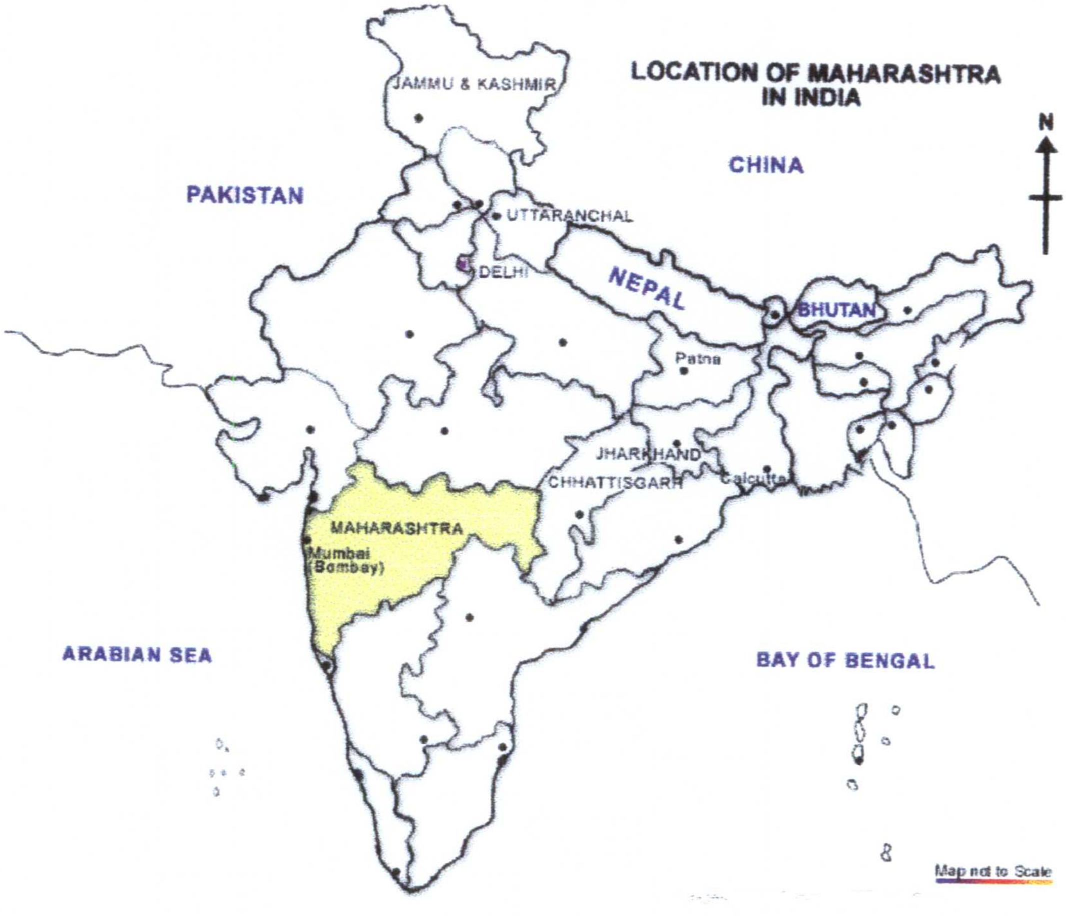

Figure 1: Location of Maharashtra (source: www.mapsof india.com)

Modeling can be defined as the application of mathematical techniques to quantify any aspects of the size or of the harvesting process applied to it, The major objectives of model formulation in fisheries include the study of input-output relationship, suggestion of management strategies for optimum utilization of resources and prediction of the size of the resources or catch, given the set of condition. Predictive models would enable the fishing fleet to adopt the fishing fleet to adopt appropriate strategies for exploitation, post harvest handling and marketing arrangements and provide scope for the optimum level of financial preparedness to make the best of fish catch.

The following two broad approaches are usually used to model a dynamic process like fish landings:

i) Deterministic regression techniques that explain changes in terms of changes in various biotic and abiotic variables.

ii) Time series techniques that treat the system as a black box, viewed as an unknown generating process and forecasting is based on projection of past values of a variable.

In the present study the second approach viz. univariate time series analysis is used. In the Time series analysis proposed by Box-Jenkins (1970), which is now popular, both moving average terms and autoregressive terms are tested in a standardized procedure. Autoregressive terms may sometimes be interpreted in terms of such biological phenomena as reproductive time lags; where as the moving average terms that is based on differences between predicted and observed values of a series are easily interpreted.

The phrase "time -series analysis" is used in several ways. Some times it refers to any kind of analysis involving time-series data. While at other times it is used more narrowly to describe behavior of time-series data using only past observations on the variable in the question. Latter activity is referred as *single-series* or *univariate analysis.* Univariate Box

Jenkins Auto Regressive Integrated Moving Average (UBJ-ARIMA) modeling is a type of univariate analysis. UBJ-ARIMA models are especially suited to short term forecasting as most ARIMA models place heavy emphasis on the recent past than the distant past .The main objective of the present study is the predictive modeling of marine fish landings of Maharashtra coast using UBJ-ARIMA models.

Review of Literature

2. REVIEW OF LITERATURE

2.1 International status

Jensen (1976) examined the autocorrelation structure of Atlantic menhaden and used a second order autoregressive model for the prediction of menhaden catch. Dyer and Gillooly (1979) studied the variations over time of the total annual production of pelagic fish for South Africa and the United Kingdom quantitatively using the exponential smoothing technique. The exercise was repeated on annual mackerel landings for the same two countries. Van Winkle *et al.* (1979) used autocorrelation and spectral analysis techniques to examine the periodicity in the dominant year classes of Atlantic coast striped bass (Morone saxatilis) commercial fisheries data.

Mendelssohn (1980) used Box –Jenkins method models to forecast fishery dynamics. Saila *et al.* (1980) compared some time-series models for analysis of fisheries data and found Auto Regressive Integrated Moving Average (ARIMA) model to be the most suitable in terms of producing forecasts upto 12 months ahead. Stocker and Hillborn (1981) considered the predictive power of stock production models and some time series methods for five marine fish stocks.

Anderson (1982) made an empirical estimation of Box –Jenkins procedure of forecasting which consisted of data transformation, model identification, parameters estimation and diagnostic checking. Abraham and Ladolter (1984) suggested inverse autocorrelation as a model identification tool for time series data models. Inverse autocorrelation was less powerful than partial autocorrelation for an autoregressive process.

Jensen (1985) analyzed the catch and catch per unit effort data for Atlantic menhaden and the gulf menhaden of the Gulf of Mexico with the help of autocorrelation to test for time lags and to develop forecasting equations. Noakes (1985) demonstrated the efficiency of intervention analysis in fisheries science using the data from the Canadian Dungeness crab fishery. Rose *et al.* (1986) proposed a time series analysis method based on the use of categorized variables and ordinary least squares method. They contended that it had several advantages over the Box-Jenkins models and time series regression with continuous variables. Aspects of model building, significance testing and interpretation of the results were discussed and illustrated with a fisheries example involving a measure of white perch (Morone americana) stock size in the Delaware River/Bay from 1928 to 1974.

Box *et al.* (1987) came up with a mechanism for estimation of trend of a multiplicative seasonal ARIMA model as a component of the models forecast function which is a linear combination of roots a of the autoregressive operator that are associated with the trend. Poskitt and Tremayne (1987) purposed selection criteria for order determination via posterior odd ratios and the application of grapes of evidence proposed by Geffreys (1961).

Differencing is done to transform nonstationary series into stationary ones. Cressie (1988) could identify an amount of differencing "d" in an ARIMA (p, d, q), which can be read from a sequence of graphs based on the concept of generalized covariance known as variograms.

Fogarty (1988) used Box-Jenkins transfer function models to analyze the relationship between water temperature and Marine lobster catch and catch per unit effort (CPUE). Stergiou (1989) analyzed 17-year record of monthly catch of pilchard from Greek waters using the ARIMA techniques and proposed two models suitable to describe the dynamics of the fishery for forecasting catches upto 12 months ahead. Stergiou (1990) also presented a seasonal autoregressive model of the Anchovy fishery in the Eastern Mediterranean. He found that the seasonal autoregressive terms of the model seemed to be consistent with the biological/oceanographic observations.

Stergiou and Christou (1996) and Stergiou *et al.* (1997) compared the performance of regression, univariate and multivariate time series models, harmonic regression models and exponential smoothing techniques (seasonal and non-seasonal) in predicting the monthly fisheries catches of 16 species in the Hellenic waters.

ARIMA *modeling and forecasting* the Albacore *catch and* CPUE of Taiwanese Tuna long line fishery in the South Atlantic Ocean was done by Chi –Lu Sun and Su Zan Yeh (1998). They used time series of the monthly catch and the monthly catch per unit effort (CPUE) of the South Atlantic albacore harvested by the Taiwanese long line fishery from January 1968 to December 1993. Box –Jenkins Auto –regressive Integrated Moving Average (ARIMA) models were evaluated to as their efficiency in the short term forecasting of the fishery. Although they have high forecasting errors, the models may provide a useful measure of the likely ranges of the catch and CPUE for the management of the albacore stock in the South Atlantic Ocean. Kuikka et.al (1999) modeled environmentally driven uncertainties in Baltic Cod (*Gadus morhua)* management by Bayesian influence diagrams.

Hobday and Bochlert (2001) studied the role of coastal ocean variation in spatial and temporal pattern in survival and size of Coho salmon (Oncorhynchus kitsutch) of three geographic regions (North of Vancouver Island, Puget Sound and Strait of Georgia and the outer coast south of tip of Vancouver Island) along North American range.

2.2 National status

Time series and trend analysis have been frequently applied in India in fishery forecasting. Noble (1972) studied the relation between the duration of the mackerel fishery and minimum temperature observed at the surface in the inshore sea water during the south-west monsoon period and indicated its usefulness in advance prediction of the duration of the mackerel fishery. He also discussed the relation between the catch and the local rainfall and DO in the seawater.

Antony Raja (1973) studied oil sardine fishery and related it to rainfall and availability of juveniles in July-September. Chakroborty (1973) and Shastri (1978) carried out polynomial regression analysis on time series of marine fish landings.

Noble (1980) analysed mackerel landings in India for 3 decades and found a set pattern of recurring ups in and around the confluence of 2 decades and down in the middle of one decade. He suspected the presence of a ten-year cycle in the mackerel fishery.

In India the first ever attempt on modelling marine fish production using the Box-Jenkins approach was by Indian Institute of Management (Anon, 1984). In this study, the quarterly marine fish landings during 1960 to 1978 in each of the maritime states of India were considered for building up multiplicative seasonal auto-regressive models. The models were then used to forecast the fishery from 1979 to 1985. The forecasted values were found to be more or less in good agreement with the observed values.

Srinath and Dutta (1985) applied the ARIMA modelling to the marine fish products export in India. They demonstrated the feasibility of ARIMA technique in forecasting and found that the forecasts were closer to the actual values. Noble and Sathianandan (1991) applied ARIMA models to study the trend in all India mackerel catches.

Biradar *et al.* (1991) attempted forecasting of quarterly marine fish landings of Maharashtra coast based on mean minimum temperature in the last 3 quarters. Sathianandan and Srinath (1995) also attempted forecasting of total marine fish landings and those of some important groups using Box-Jenkins ARIMA model. Ayoob (1996) used different smoothing techniques and ratio to moving average method for forecasting marine fish landings of Maharashtra. Venugopal and Prajneshu (1996) carried out comparative study of polynomial function fitting approach and ARIMA time series methodologies for describing the all-India marine product exports during 1960-61 to 1994-95. Srinath (1996) carried out Markov chain application to the dynamics of the pelagic fishery along the Kerala coast.

Sathianandan and Alagaraja (1998) carried out spectral decomposition of all India landings of Bombay duck. Venugopal and Srinath (1998) evaluated three different statistical modelling procedures, viz. Deterministic regression modelling, univariate time series and multivariate time series modelling approaches, to provide accurate operational forecasts of the quarterly commercial landings of seven species of marine fishes along with the total landings of Tamil Nadu. The forecasts were based on the database of 1979-1996.

Srinath (1998) carried out an exploratory analysis on the predictability of oil sardine landings of Kerala. The analysis has revealed, albeit tentatively, the possible factors causing short-term and long-term variations in the catches of the oil sardine. Predictive models based purely on the autocorrelations and cyclic trend suggest possibility of generating forecasts which can be validated taking into consideration the long-term and year to year concomitant variations in the correlated factors. Sathianandan (2000) used multiple time series models for modelling and forecasting of marine fish landings of Kerala.

Material and methods

3. MATERIAL AND METHODS

3.1 Data base

Data types

The univariate Box –Jenkins model applies either to discrete data or continuous data. Although the univariate Box –Jenkins method can handle either discrete or continuous data it deals only with data measured at equally spaced, discrete time intervals. Data measured at discrete time intervals can arise in two ways. First a variable may be accumulated through time and the total recorded periodically. Univariate Box –Jenkins ARIMA models are particularly useful for forecasting data series that contain seasonal (or other periodic) variation, including those with shifting seasonal patterns.

Sample Size

Building an ARIMA model requires an adequate sample size. Box and Jenkins suggested that about 50 observations is the minimum required number. Some analysts may occasionally use a smaller sample size, interpreting the results with caution. A large sample size is especially desirable when working with seasonal data.

Stationary Series

The Univariate Box –Jenkins- ARIMA method applies only to stationary data series .A stationary time series has mean, variance and auto correlation functions that are essentially constant through time. If a data series has stationary then the variance of any major subset of the series will differ (from the variance of any major subset of the series will differ) from the variance of any other major subset only by chance.

Data collection

The data for the study were obtained from reports of Department of Fisheries, Government of Maharashtra and the Central Marine Fisheries Research Institute, Cochin .In the present study, the quarterly total landings and quarterly landings of Bombay duck, carangids, catfishes, mackerel and non-penaeid prawns for the Maharashtra state for the period 1975-1999 formed the data base for the present study. The quarters of each year being January-March. April-June, July-September and October-December. Thus for time series analysis there were 100 observations for each species under consideration and for total landings. For the computation of compound growth rate annual landings during the period 1980-1999 were only considered.

3.2. Area study and species selection

The area of study was the entire Maharashtra coastline of 720 km in length with 5 maritime districts -Thane, Greater Mumbai, Raigarh, Ratnagiri and Sindhudurgh. District map of Maharashtra is given in Fig.2.

Figure 2 : District Map of Maharashtra(source : www.maps of India.com)

3.2 Analysis of growth

The growth in fish landings was analyzed by using the exponential growth function of the form,

$$Y = ab^t e \quad \text{.....................} \quad (3.1)$$

where,

Y = Dependent variable for which growth rate is estimated

a = Intercept

b= Regression co-efficient

t= Time variable

e = Error term

Taking logarithm to the base (ln) on both sides of (3.1), the following equation is obtained:

$$\ln Y = \ln a + (\ln b)\, t + \ln e$$

$$\ln Y = A + Bt + E \text{ ....} \quad (3.2)$$

where A = ln a, B = ln b and E = ln e. The constants A and B of equation (3.2) were estimated using the method of least squares.

Then, the per cent compound growth rate (g) was computed by using the relationship

$$g = (e^{B} - 1) \times 100 \quad \text{................} \quad (3.3)$$

3.3 The Box- Jenkins modeling procedure

3.3.1 Auto Regressive Integrated Moving Average (ARIMA)

An **ARIMA** model is an algebraic statement showing how a time-series variable (z_t) is related to its own past values ($z_{t-1}, z_{t-2}, z_{t-3}...$). Consider the algebraic expression $z_t=C+\emptyset_1 z_{t-1}+a_t$-------------------------------- **(3.4)**

Equation 3.4 is an example of an **ARIMA** model. It says that z_t is related to its own immediately past value (z_{t-1}). **C** is a constant term. $\emptyset_1$ is a fixed coefficient whose value determines the relationship between z_t and z_{t-1}. The a_t term is a probabilistic "shock" element.

The terms **C,** $\emptyset_1 z_{t-1}$ and a_t are each components of z_t. **C** is a deterministic (fixed) component, $\emptyset_1 z_{t-1}$ is a probabilistic component since its value depends in part on the value of z_{t-1}, and a_t is a purely probabilistic component. Together C and $\emptyset_1 z_{t-1}$ represent the predictable part of z_t while a_t is a residual element that cannot be predicted within the **ARIMA** model.

A good model includes the smallest number of estimated parameters needed to adequately fit the patterns in the available data.

Box and Jenkins propose a practical three-stage procedure for finding a good model. The three-stage Univariate Box Jenkins procedure is summarized schematically in figure 3.

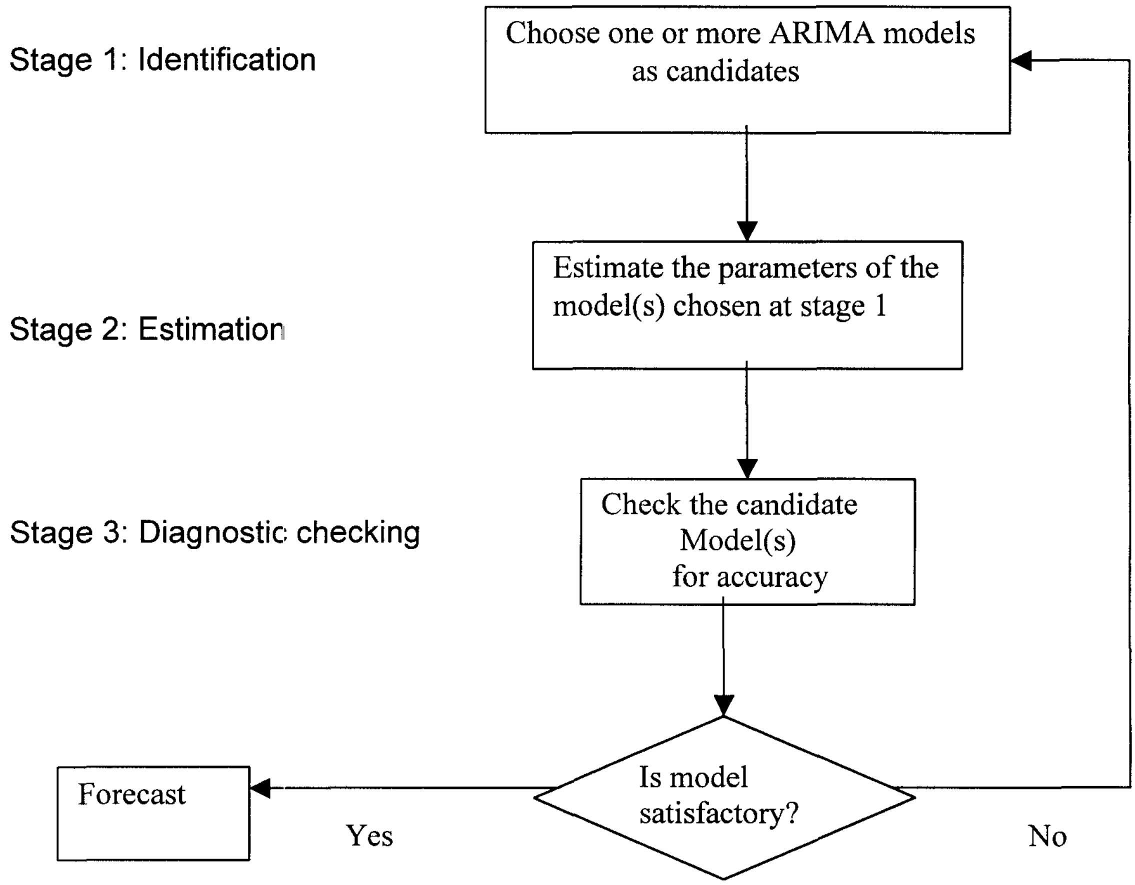

Figure 3 : Stages **in the Box-Jenkins iterative approach to model building**

(Adapted from Box and Jenkins [1983])

STAGE –1: IDENTIFICATION. At the identification stage two devices are used to measure the correlation between the observations within a single data series. These devices are called an estimated *autocorrelation function* (abbreviated acf) and an estimated *partial autocorrelation function* (abbreviated pacf). The estimated acf and pacf measure the statistical relationship within a data series in a somewhat crude way. Nevertheless, they are helpful in giving us a feel for the pattern in the available data.

The next step at the identification stage is to summarize the statistical relationships within a data series in a more compact way. Box and Jenkins suggest a whole family of algebraic statements (**ARIMA** models) from which one may be chosen. Equation (3.4) is an example of such a model.

Estimated acf and pacf are used as guides for choosing one or more **ARIMA** models that seem appropriate. The basic idea is that every **ARIMA** model (such as equation 3.4) has a *theoretical* acf and pacf associated with it. At the identification stage the *estimated* acf and pacf calculated from the available data with various *theoretical* acf and pacf's are compared. Then tentatively choose the model whose theoretical acf and pacf most closely resemble the estimated acf and pacf of the data series.

Whichever model is chosen at the identification stage is considered only as tentative. It is only a candidate for the final model. In order to choose a final model proceed to the next two stages and perhaps return to the identification stage if the tentatively considered model is inadequate.

STAGE 2: ESTIMATION. At this stage precise estimates of the coefficients of the model chosen at the identification stage are available. For example, if equation 3.4 is tentatively chosen as our model, this model is fitted to the available data series to get estimates of $\boldsymbol{\varnothing_1}$ and **C**. This stage provides some warning signals about the adequacy of our model. In particular, if the estimated coefficients do not satisfy certain mathematical inequality conditions, that model is rejected.

STAGE 3: DIAGNOSTIC CHECKING. Box and Jenkins suggest some diagnostic checks to help determine if an estimated model is statistically adequate. A model that fails these diagnostic tests is rejected. Further more, the results at this stage may also indicate how a model could be improved. This will lead back to the identification stage. Repeat the cycle of identification, estimation, and diagnostic checking until a good final model is chosen.

3.3.2 Three process and ARIMA (p, d, q) notation

The ordinary algebraic forms of the two common **ARIMA** processes viz. **AR (1)** and **MA (1)** are:

$$z_t = C + \varnothing_1 z_{t-1} + a_t \quad \text{(3.5)}$$

$$z_t = C - \theta_1 a_{t-1} + a_t \quad \text{(3.6)}$$

Here are three additional processes to consider:

$$z_t = C + \varnothing_1 z_{t-1} + \varnothing_2 z_{t-2} + a_t \quad \text{(3.7)}$$

$$z_t = C - \theta_1 a_{t-1} - \theta_2 a_{t-2} + a_t \quad \text{(3.8)}$$

$$z_t = C + \varnothing_1 z_{t-1} - \theta_1 a_{t-1} + a_t \quad \text{(3.9)}$$

Equation (3.7) is called an AR (2) process because it contains only AR terms (in addition to the constant terms and the random shock), and the maximum time lag on the AR terms is two. Process (3.8) is called an MA (2) since it has only MA terms, with a maximum time lag on the MA terms of two. Equation (3.9) is an example of a mixed process ---it contains both AR and MA terms. It is an ARMA (1,1) process because the AR order is one and the MA order is also one.

Let the AR order of a process be designated *p* where *p* is some nonnegative integer. Let *q* also a nonnegative integer, be the MA order of a process. Let *d*, another non-negative integer; stand for the number of times a realization must be differenced to achieve a stationary mean. After a differenced series has been modeled, it is *integrated d* times to return to the data to the appropriate overall level. The letter "I" in the acronym ARIMA refers to this integration step and it corresponds to the number of times (*d*) the original series has been differenced; if a series has been differenced d times, it must be subsequently be integrated d times to return it to the original overall level.

ARIMA processes are characterized by the values of p, d, and q in this manner: ARIMA (p, d, and q). For example, equation (3.7) is an ARIMA (2,0,0) process, or simply an AR (2). Equation (3.8) is an ARIMA (0,0,2) process, or simply an MA (2). And (3.9) is an ARIMA (1,0,1) or an ARMA (1,1). This notation becomes more complicated when we deal with a certain type of seasonal process.

Some coefficients with lag less than the order of a process could be zero. For example if θ1 in the process (3.8) is zero, that process is written more simply as

$$Z_1 = C - \theta_2 a_{t-2} + a_t \text{ -- (3.10)}$$

Equation (3.10) is still an MA (2) process because the maximum lag on past random shock terms are two.

3.3.3 Back shift notation

ARIMA models are often written in back shift notation. The important thing is to practice translating ARIMA models written in back shift form into both ARIMA (p, d, q) form and common algebraic form. Back shift operator **B** operates such that z_t is multiplied by **B**, z_{t-1} is obtained

$$\text{Viz.,} B z_t = z_{t-1} \text{ ---------------------------- } (3.11)$$

In equation (3.11) the exponent of **B** is one and any number raised to the power one is the same number, we need not explicitly write the exponent when it is one. But the exponent of **B** might be two, for example Multiplying z_t by B^2 gives

$$B^2 z_t = z_{t-2} \text{ ------------------------ } (3.12)$$

The same pattern holds good for other exponents of **B**.In general multiplying z_t by B^k gives z_{t-k}.Thus by definition

$$B^k z_t = z_{t-k} \text{ ------------------------------ } (3.13)$$

The procedure is given in six steps:

1. Start with a variable that has been transformed (if necessary) so that it has a constant variance.

2. Write z_t in deviation from its mean: $\tilde{z}_t = z_t - \mu$.

3. Multiply $\tilde{z}_t$ by differencing the operator $(1-B)^d$ to ensure that we have the multiplier that is stationary.

4. Multiply the results from step 3 by the *AR Operator* whose general form is $(1-Ø_1B - Ø_2B^2 - ... - Ø_pB^p)$ .For a specific process assign the appropriate numerical value to ***p***, the order of the AR part of the process. If any Ø coefficients with less than ***p*** are zero, exclude those terms form the AR operator.

5. Multiply the random shock a_t by the MA *operator* whose general form is $(1- θ_1B - θ_2 B^2 - ... - θ_qB^q)$. For a specific process assign the appropriate numerical value to q, the order of the MA portion of the

process. If any θ coefficients at lags less than q are zero, exclude them from the MA operator

6. Equate the results form steps 4 and 5.

Combining the above six steps, a non-seasonal process in back shift notation has this general form :

$$(1 - \varnothing_1 B - \varnothing_2 B^2 - \ldots - \varnothing_p B^p)\ (1 - B)^d \check{z}_t$$

$$= (1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^{q)}\ a_t \text{------------------------} \quad (3.14)$$

Equation (3.14) can be written in a compact form that often appears in time series literature. Define the following symbols:

$$\blacktriangledown^d = (1-B)^d$$

$$\varnothing (B) = (1 - \varnothing_1\ B - \varnothing_2 B^2 - \ldots\ \varnothing_p B^p)$$

$$\Theta (B) = (1 - \theta_1 B - \theta_2 B^2\ \theta_q B^q)$$

Substituting each of these into (3.14) we get

$$\varnothing (B)\ \blacktriangledown^d\ \tilde{z}_t = \theta (B)\ a_t \ldots\ldots\ldots\ldots \quad (3.15)$$

Many realizations contain both seasonal and nonseasonal patterns. In such cases **the general model is given by:**

$$\phi(B)\ \varphi(B^s)\ \nabla^d \nabla_s^d\ z_t = \theta(B)\Theta(B^{s)} \text{---------------------} \quad (3.16)$$

$\phi(B)$ is the non seasonal AR operator,

$\varphi(B^s)$ is the seasonal AR operator,

$\theta(B)$ is the non-seasonal MA operator,

$\Theta(B^{s)}$ is the seasonal MA operator and

$\nabla^d \nabla_s{}^d$ are differencing operators

The general ARIMA model is specified as ARIMA (p,d,q)(P,D,Q)4. That is the order of auto regression is p, order of differencing is d, order of moving average term is q, order of seasonal auto regression is P, order of seasonal differencing is D, order of seasonal moving average term is Q and seasonality is 4.

For estimation of parameters of the model "trends " module in SPSS software was used. The algorithm used in this module for ARIMA estimation is the one given by Melard (1984). This is a fast algorithm for calculating exact likelihood of a stationary ARIMA model. Identification of an ARIMA model is carried out using criterion selection where the order *p* and *q* are determined by minimizing a quantity that is a function of the estimate of white noise variance and the order. Among this methods the popular criteria are one proposed by Akaike (1972) known as AIC criterion and the other Bayesian Information criterion proposed by Schewatz known as SBC. Adequacies of the fitted model were confirmed from t – values and standard error.

Results

4. RESULTS

The analysis was done on quarterly total marine fish landings and quarterly landings of Bombay duck, carangids, catfishes and non-penaeid prawns of Maharashtra coast. Annual Compound growth rate for the decade (1980-1989) and previous decade (1990-1999) were worked out. Quarter wise landing data of total fish landings and five species during 1975-1999 were used to identify and estimate suitable univariate autoregressive moving average models.

4.1 Trend Analysis

4.1.1 Landings

The average total landings in 1975-1999 period was 0.340 million tonnes with a range of 0.239 million to 0.452 million tonnes. During 1980-1989 and 1990-1999 the average total landings were 0.295 million tonnes and 0.385 million tonnes respectively (table-1). It is found that Bombay duck had mean landings of 48567 tonnes and 45702 tonnes during 1980-1989 and 1990-1999 respectively. Mackerel landings showed tremendous increase from average landings of 3260 tonnes in eighties to 21196 tonnes in nineties. Average landings of Carangids were almost the same in 1980-1989 and 1990-1999. Catfishes showed a decline in average landings from eighties to nineties. On the other hand Penaeid prawns showed the increase in average landings during 1990-1999 as compared to 1980-1989.

4.2 Growth Rate

The annual compound growth rates for total landings and for five species under study are given in table-2. Total landings showed a positive growth during both eighties and nineties. Bombay duck though had a negative growth in 1980-89, it showed positive growth rate of about 9% in 1990-1999. Mackerel showed very high growth rate of about 90% during eighties and 12%

in nineties. Though average landings of non-penaeid prawns were higher in 1990-1999 as compared to 1980-1989, the growth rate during both the decades was however negative.

4.3 Modeling

4.3.1 Autocorrelation, Partial Autocorrelation and Identification

As an initial step towards model building for the quarter wise *total marine fish landings, Bombay duck, carangid, catfish landings, Mackerel and non-penaeid prawn landings, the* autocorrelation function (acf) and partial autocorrelation function (pacf), were computed up to lag 24 for the original series. First order differenced series, seasonally differenced series and for the data generated by applying both regular and seasonal differences of order one and are presented in tables 3,4, 5,6,7 and 8 respectively.

The analysis of acf and pacf values indicates the seasonality of data and a suitable seasonal model may give better approximation for generating process. Since the acf and pacf does not give any clear idea about the orders of the model the alternative approach using the AIC and SBC criterion were used for model identification.

For estimating the order parameters of the model ARIMA (p, d, q)(P, D, Q) s viz.p, d, q, P, D and Q, AIC and SBC values were calculated along with log likelihood and standard error, after fitting each model from a set of 1800 models corresponding to different values of the order parameters taking values p, q=0,1,2..,5 ; P=0,1,2; Q=1,2,..5 and d,D=0,1.

For total marine fish landings, the autocorrelation and partial auto correlation values were analyzed. Auto correlations of the original series showed highly significant values at lags that are multiple of four and the strength of auto correlations was found decreasing as the lag increases.

The maximum auto correlations observed for the series was 0.794 at lag 4 The data being quarter wise landings this is an indication of seasonality of period 4 present in the data. Autocorrelations of first order differences also showed the similar trend as noticed in original series. The maximum autocorrelation observed was again at lag 4 (0.828). The pacf was highly significant for lag 4 for the original series and lag 3 for the differenced series. For the regular and seasonal difference, the lag 1 showed maximum acf and pacf value. But this analysis does not show any pattern helpful for identification of orders of a suitable ARIMA model apart from showing that the data is seasonal and a suitable seasonal model may give better approximation for the generating process .

For Bombay duck acf of the original series showed highly significant values at lags that are multiple of four. The maximum auto correlations observed for the series was 0.662 at lag 4 (table-4). The data being quarter wise landings this is an indication of seasonality of period 4 present in the data. The autocorrelations of first order differences also showed similar trend as noticed in original data. The maximum autocorrelations observed for first order difference was again at lag 4 (0.721). The pacf was significant at lag 4. For the first order differenced data the acf was highly significant at lags 1and 3. This analysis was however not helpful in identification of suitable ARIMA model except showing the data is seasonal and seasonal model may better describe the process.

In carangid landings the original and also differenced series showed significant correlations for lags that are multiple of four (table-5). The maximum autocorrelation is found at lag 4 with a value 0.513 for the differenced series. The pacf was maximum at lag 4 for the original series, while significant negative pacf was observed at lag 3 for the first order differenced series.

In the analysis of catfish landings the study reveals that acf were higher for lags that are multiples of 4, for both original and differenced series, with the latter showing higher values (table-6). The acf and pacf were significant at lag 4 with seasonal as well as seasonal and regular differenced series showing negative values.

Like in other species, acf of original and first order differenced series for mackerel were highly significant at lags that are multiples of 4 (table-7). The pacf values were higher for lags of 4,8 and 12. The acf and pacf for seasonally differenced data were also significant at lag 4, but negative.

For Non - penaeid prawn landings, acf and pacf values at lag 4 and 8 were significant with the latter being higher than the former (table -8). The pacf of the differenced series was negative and highly significant at lag 3.

Thus acf and pacf showed that landings of the species under study are seasonal and hence models with suitable seasonal and non - seasonal patterns may better describe the generating process.

4.3.2 Fitting

Total marine fish landings

The ARIMA model found suitable for total marine fish landings data is ARIMA (0,0,0)(0,1,1)4 . That is the order of auto regression is 0, order of differencing is 0, order of moving average term is 0, order of seasonal auto regression is 0, order of seasonal differencing is unity, order of seasonal moving average term is 1 and seasonality is 4.

The iteration process in estimation of this process was terminated after several iterations when the change in parameter estimate was less than 0.0001. The final estimate of variables of the model are θ_1 =0.6843816(table-9). It can be seen that the parameter is significant at 1% level of significance. The loglikelihoodf for this estimate was found to be -1091.0378. The AIC and SBC values are 2184.076 and 2186.64 respectively.

The algebraic form of the final estimated model for total landings as per equation (3.16) is :

$$(1-B^4)\, z_t = (1-0.6843816\, B^4)\, a_t$$

or

$$z_t = z_{t-4} + a_t - \theta_1 a_{t-4}$$

The model to be fitted for the different species may also be derived in the same way. The models fitted for other species are given in tables-10,11,12,13 and 14. The parameters of all the models were highly significant at 1% level of significance. For the estimates of the model of Bombay duck the loglikelihood of was found to be -976.89134. The AIC and SBC values were 1965.783 and 1981.106 respectively. The loglikelihood for the estimates of model of carangids was found to be -856.98359. The AIC and SBC values are 1721.967 and 1732.183 respectively. For the estimates of model of cat fishes loglikelihood was found to be -797.84439. The AIC and SBC values are 1599.689 and 1604.797 respectively. The estimates of model of Mackerel showed a loglikelihood value of -905.32853 with an AIC and SBC value of 1826.657 and 1847.088 respectively. For the estimates of model of non-penaeid prawns the loglikelihood value was -975.18138 with the AIC and SBC value 1960.363 and 1973.113 respectively.

4.3.3 Prediction

The fitted model is used to forecast quarterly landings for the years 2000 and 2001. All the data from 1975 till 1999 on quarterly basis is used for the purpose. Comparison of forecast value with observed value is assessed in the form of graph. The observed value for each of the fitted model is then compared with that of fitted value in the respective figures –3, 4, 5, 6, 7 and 8 for total landings, Bombay duck, carangid landings, cat fishes, mackerel and non-penaeid prawns. The observed catch, estimated catch and standard error for the fitted models are shown in table-16.

Table-1 : Mean and range of fish landings (in tonnes) of different species /groups during 1980-1999

Species groups	Mean		Range	
	1980-89	1990-99	1980-89	1990-99
Total landings	294752.9	384804.3	231763 to 362330	327695 to 451821
Bombay duck	48566.9	45701.8	25222 to 82136	14994 to 71998
Carangids	7650.4	7681.3	1509 to 22452	2745 to 14215
Cat fishes	12490	9282.2	8653 to 21086	5835 to 12284
Mackerel	3260.1	21195.7	258 to 22353	2364 to 32234
Non-Penaeid	42372.4	53692.7	20234 to 57387	30513 to 89519

Table-2 : Annual compound growth rates (%)

SPECIES	1980-1989	1990-1999
Total landings	3.82	2.63
Bombay duck	-9.51	9.41
Carangids	30.97	-15.98
Cat fishes	5.34	0.202
Mackerel	89.66	12.09
Non-penaeid prawns	-3.04	-2.41

Table- 3 : Auto correlation and partial autocorrelation values computed for the time series on Total landings in Maharashtra (1975-99)- (I) original series (ii) first order difference (iii) seasonal difference (iv) both regular and seasonal difference

Autocorrelation					Partial autocorrelation				
Lag	I	ii	iii	iv	Lag	I	ii	iii	iv
1	-0.146	-0.509	0.107	-0.465	1	-0.146	-0.509	0.107	-0.465
2	-0.09	0.05	0.036	0.066	2	-0.114	-0.283	0.025	-0.191
3	-0.167	-0.456	-0.131	0.007	3	-0.206	-0.833	-0.139	-0.06
4	0.794	0.828	-0.283	-0.295	4	0.777	0.193	-0.263	-0.404
5	-0.143	-0.406	0.067	0.293	5	-0.052	0.121	0.139	-0.075
6	-0.112	0.005	-0.104	-0.158	6	-0.081	-0.154	-0.128	-0.126
7	-0.136	-0.393	-0.005	0.158	7	0.098	-0.248	-0.067	0.041
8	0.721	0.766	-0.186	-0.167	8	0.238	0.131	-0.25	-0.237
9	-0.171	-0.4	-0.05	-0.027	9	-0.136	-0.144	0.033	-0.197
10	-0.096	0.031	0.121	0.15	10	0.065	-0.074	0.067	-0.041
11	-0.125	-0.373	0.023	-0.034	11	0.03	-0.075	-0.052	0.102
12	0.68	0.724	-0.058	-0.043	12	0.112	0.013	-0.255	-0.211
13	-0.19	-0.381	-0.05	-0.032	13	-0.051	-0.019	0.034	-0.202
14	-0.125	0.016	0.032	0.056	14	-0.084	-0.074	0.091	0.009
15	-0.132	-0.321	0.006	0.025	15	-0.043	-0.017	-0.094	0.13
16	0.616	0.661	-0.039	-0.007	16	0.007	0.012	-0.248	-0.098
17	-0.179	-0.334	-0.09	-0.02	17	0.02	0.095	-0.075	-0.159
18	-0.16	-0.027	-0.092	-0.08	18	-0.113	-0.052	0.017	-0.1
19	-0.101	-0.282	0.056	0.104	19	0.072	-0.081	0.029	0.187
20	0.601	0.63	0.013	-0.122	20	0.129	0.05	-0.27	-0.241
21	-0.15	-0.311	0.159	0.233	21	0.05	0.06	0.088	-0.005
22	-0.158	-0.04	-0.094	-0.171	22	0.003	0.004	-0.083	-0.016
23	-0.108	-0.28	-0.053	-0.071	23	-0.021	-0.092	-0.052	-0.01
24	0.587	0.645	0.14	0.237	24	0.087	0.177	-0.033	0.031

Table-4 : Auto correlation and partial autocorrelation values computed for the time series on Bombay duck landings in Maharashtra (1975-99)- (I) original series (ii) first order difference (iii) seasonal difference (iv) both regular and seasonal difference

Autocorrelation					Partial Autocorrelation				
Lag	I	ii	iii	iv	Lag	I	ii	iii	iv
1	-0.179	-0.567	0.072	-0.495	1	-0.179	-0.567	0.072	-0.495
2	-0.008	0.165	0.057	0.049	2	-0.041	-0.23	0.052	-0.26
3	-0.22	-0.461	-0.045	0.096	3	-0.237	-0.741	-0.054	-0.003
4	0.662	0.721	-0.304	-0.3	4	0.632	0.081	-0.303	-0.324
5	-0.181	-0.404	-0.026	0.169	5	-0.081	0.066	0.02	-0.215
6	-0.046	0.128	-0.057	-0.06	6	-0.098	-0.038	-0.021	-0.194
7	-0.216	-0.406	0.025	0.205	7	-0.017	-0.24	0.007	0.198
8	0.56	0.623	-0.282	-0.37	8	0.197	0	-0.414	-0.41
9	-0.171	-0.344	0.105	0.271	9	-0.049	-0.036	0.189	-0.129
10	-0.042	0.13	-0.011	-0.027	10	-0.013	-0.021	-0.026	-0.018
11	-0.228	-0.421	-0.08	-0.185	11	-0.045	-0.267	-0.133	-0.109
12	0.582	0.665	0.167	0.299	12	0.26	0.159	-0.066	-0.155
13	-0.206	-0.39	-0.117	-0.241	13	-0.126	0.013	-0.008	-0.143
14	-0.04	0.136	0.047	0.091	14	-0.029	-0.096	0.019	-0.085
15	-0.199	-0.329	0.04	0.032	15	0.079	0.157	-0.018	0.017
16	0.446	0.504	-0.003	-0.024	16	-0.135	-0.067	-0.128	-0.132
17	-0.162	-0.291	-0.026	-0.001	17	0.053	-0.031	0.018	-0.065
18	-0.046	0.104	-0.036	-0.036	18	0.01	0.01	-0.026	-0.041
19	-0.172	-0.276	0.024	0.158	19	-0.004	0.027	-0.036	0.147
20	0.362	0.429	-0.218	-0.313	20	-0.049	0.031	-0.262	-0.246
21	-0.136	-0.255	0.114	0.236	21	0.015	-0.014	0.108	-0.135
22	-0.032	0.099	0.013	-0.098	22	0.023	0.001	0.046	-0.171
23	-0.159	-0.294	0.094	-0.053	23	0.005	-0.114	0.117	-0.052
24	0.423	0.518	0.27	0.235	24	0.16	0.208	0.027	-0.136

Table- 5 : Auto correlation and partial autocorrelation values computed for the time series on carangid landings in Maharashtra (1975-99)- (I) original series (ii) first order difference (iii) seasonal difference (iv) both regular and seasonal difference

Autocorrelation					Partial autocorrelation				
Lag	I	ii	iii	iv	Lag	I	ii	iii	iv
1	0.179	-0.385	0.204	-0.28	1	0.179	-0.385	0.204	-0.28
2	-0.012	-0.162	-0.146	-0.243	2	-0.045	-0.364	-0.196	-0.348
3	0.062	-0.215	-0.109	0.193	3	0.075	-0.595	-0.037	0.005
4	0.492	0.513	-0.38	-0.394	4	0.485	0.031	-0.406	-0.5
5	0.078	-0.282	-0.023	0.031	5	-0.112	-0.278	0.162	-0.33
6	0.127	0.073	0.285	0.397	6	0.212	-0.017	0.136	0.017
7	0.056	-0.232	-0.038	-0.043	7	-0.038	-0.249	-0.19	0.173
8	0.366	0.41	-0.293	-0.305	8	0.203	0.09	-0.424	-0.413
9	0.003	-0.21	-0.062	0.179	9	-0.131	0.077	0.158	-0.139
10	-0.017	-0.076	-0.117	-0.153	10	-0.124	-0.198	-0.051	-0.166
11	0.088	-0.207	0.071	-0.037	11	0.155	-0.361	-0.001	-0.055
12	0.533	0.603	0.318	0.32	12	0.328	0.138	-0.102	-0.266
13	-0.01	-0.311	0.059	-0.13	13	-0.17	-0.073	0.145	-0.225
14	-0.044	-0.076	0.006	-0.061	14	0.044	-0.015	0.145	-0.077
15	0.048	-0.146	0.047	0.04	15	-0.014	-0.057	0.015	-0.114
16	0.38	0.481	0.025	0.024	16	0.031	0.128	0.061	-0.004
17	-0.073	-0.287	-0.037	-0.067	17	-0.146	0.111	-0.042	-0.082
18	-0.059	-0.016	0.01	0.114	18	-0.132	-0.017	0.038	0.052
19	-0.021	-0.118	-0.123	-0.015	19	-0.005	0.098	-0.102	0.05
20	0.212	0.337	-0.233	-0.215	20	-0.125	-0.049	-0.112	-0.079
21	-0.107	-0.201	0.003	0.139	21	0.015	0.014	0.022	-0.077
22	-0.099	-0.066	0.016	-0.065	22	-0.049	-0.121	0.025	-0.193
23	0.018	-0.081	0.132	0.034	23	0.082	-0.062	0.156	-0.079
24	0.269	0.403	0.194	0.184	24	0.026	0.018	0.054	0.088

Table- 6 : Auto correlation and partial autocorrelation values computed for the time series on *catfish* landings in Maharashtra (1975-99)- (I) original series (ii) first order difference (iii) seasonal difference (iv) both regular and seasonal difference

Autocorrelation					Partial Autocorrelation				
Lag	I	ii	iii	iv	Lag	I	ii	iii	iv
1	0.059	-0.325	0.086	-0.525	1	0.059	-0.325	0.086	-0.525
2	-0.269	-0.364	0.138	0.005	2	-0.274	-0.525	0.132	-0.374
3	0.092	-0.093	0.169	0.337	3	0.14	-0.686	0.151	0.231
4	0.626	0.63	-0.411	-0.524	4	0.588	0.037	-0.472	-0.319
5	-0.032	-0.171	-0.033	0.268	5	-0.096	0.145	0.007	-0.191
6	-0.355	-0.372	-0.137	-0.066	6	-0.211	0.017	-0.034	-0.254
7	0.009	-0.103	-0.12	-0.06	7	-0.132	-0.397	0.077	0.035
8	0.566	0.654	0.009	0.106	8	0.31	0.015	-0.196	-0.168
9	-0.101	-0.225	-0.065	-0.089	9	-0.072	-0.043	-0.022	-0.131
10	-0.338	-0.303	0.022	0.108	10	-0.008	0.077	-0.02	-0.057
11	-0.01	-0.093	-0.089	-0.059	11	-0.126	-0.142	-0.096	0.012
12	0.491	0.603	-0.089	0.019	12	0.104	0.043	-0.169	-0.031
13	-0.144	-0.229	-0.117	-0.087	13	-0.087	-0.075	-0.155	-0.291
14	-0.337	-0.307	0.005	0.031	14	0.023	-0.09	0.138	-0.155
15	0.043	-0.035	0.077	0.074	15	0.054	-0.139	0.052	0.015
16	0.49	0.546	0.013	-0.129	16	0.135	-0.042	-0.117	-0.083
17	-0.093	-0.172	0.182	0.203	17	0.06	0.145	-0.012	-0.052
18	-0.346	-0.349	-0.02	-0.149	18	-0.145	0.008	-0.036	-0.163
19	0.056	-0.009	0.049	-0.025	19	-0.023	-0.078	0.097	-0.124
20	0.477	0.568	0.16	0.172	20	0.066	0.064	0.091	-0.031
21	-0.175	-0.256	-0.048	-0.187	21	-0.065	0.014	0.003	-0.019
22	-0.338	-0.295	0.091	0.072	22	-0.011	0.025	-0.014	-0.185
23	0.046	0.036	0.099	0.135	23	-0.036	0.1	0.178	0.145
24	0.36	0.48	-0.154	-0.24	24	-0.132	0.058	-0.157	-0.052

Table- 7 : **Auto correlation and partial autocorrelation values computed for the time series on Mackerel landings in Maharashtra (1975-99)- (I) original series (ii) first order difference (iii) seasonal difference (iv) both regular and seasonal difference**

		Autocorrelation					Partial autocorrelation		
Lag	I	ii	iii	iv	Lag	I	ii	iii	iv
1	0.225	-0.378	0.064	-0.41	1	0.225	-0.378	0.064	-0.406
2	0.006	-0.28	0.019	-0.12	2	-0.047	-0.494	0.015	-0.34
3	0.265	0.006	0.108	0.394	3	0.289	-0.524	0.106	0.259
4	0.511	0.397	-0.508	-0.53	4	0.438	-0.04	-0.529	-0.389
5	0.072	-0.181	-0.095	0.149	5	-0.104	-0.027	-0.008	-0.134
6	-0.01	-0.143	-0.029	0.122	6	-0.035	0.024	-0.023	-0.142
7	0.13	-0.138	-0.207	-0.19	7	-0.098	-0.379	-0.103	0.071
8	0.475	0.483	-0.052	0.11	8	0.36	0.051	-0.392	-0.207
9	0.052	-0.22	-0.098	-0.04	9	-0.071	-0.05	-0.2	-0.138
10	-0	-0.206	-0.037	-0.06	10	0.058	-0.132	-0.043	-0.152
11	0.243	-0.036	0.144	0.037	11	0.098	-0.375	0.018	-0.095
12	0.532	0.455	0.254	0.081	12	0.301	-0.123	0.045	0.01
13	0.095	-0.179	0.206	0.059	13	0.029	0.04	0.006	0.128
14	-0.01	-0.194	0.066	-0.09	14	-0.114	0.077	-0.065	-0.067
15	0.173	-0.003	0.098	0.155	15	-0.098	0.072	0.166	0.172
16	0.346	0.333	-0.119	-0.08	16	-0.08	0.015	0.027	0.089
17	-0.03	-0.182	-0.129	-0.14	17	-0.014	0	-0.002	0.056
18	-0.06	-0.075	-0.003	0.216	18	-0.032	0.185	-0.002	0.093
19	0.017	-0.109	-0.264	-0.23	19	-0.204	0.018	-0.105	-0.034
20	0.263	0.353	-0.116	-0.02	20	0.025	0.071	-0.049	-0.069
21	-0.03	-0.16	-0.05	0.132	21	0.007	0.018	-0.055	-0.115
22	-0.08	-0.216	-0.098	-0.2	22	0.037	-0.13	-0.002	-0.093
23	0.204	0.093	0.21	0.155	23	0.191	0.008	0.041	-0.06
24	0.343	0.263	0.197	0.129	24	0.023	-0.053	0.054	0.101

Table- 8 : **Auto correlation and partial autocorrelation values computed for the time series on Non-penaeid prawn landings in Maharashtra (1975-99)- (I) original series (ii) first order difference (iii) seasonal difference (iv) both regular and seasonal difference**

Autocorrelation					Partial autocorrelation				
Lag	I	ii	iii	iv	Lag	I	ii	iii	iv
1	-0.111	-0.605	0.103	-0.472	1	-0.111	-0.605	0.103	-0.472
2	0.121	0.231	0.051	0.021	2	0.11	-0.214	0.041	-0.26
3	-0.158	-0.423	-0.037	0.107	3	-0.137	-0.634	-0.047	-0.004
4	0.5	0.582	-0.314	-0.326	4	0.48	-0.037	-0.312	-0.357
5	-0.131	-0.353	-0.011	0.167	5	-0.067	-0.001	0.057	-0.243
6	0.02	0.153	-0.004	0.057	6	-0.108	-0.073	0.028	-0.056
7	-0.165	-0.303	-0.102	-0.104	7	-0.039	-0.188	-0.14	-0.1
8	0.321	0.454	-0.014	0.121	8	0.093	0.052	-0.103	-0.092
9	-0.201	-0.319	-0.142	-0.12	9	-0.145	-0.053	-0.115	-0.167
10	-0.017	0.123	-0.053	-0.043	10	-0.049	-0.157	-0.025	-0.219
11	-0.104	-0.165	0.109	0.285	11	0.065	-0.02	0.063	0.174
12	0.177	0.247	-0.239	-0.418	12	-0.06	-0.148	-0.346	-0.33
13	-0.088	-0.174	0.162	0.255	13	0.08	-0.126	0.152	-0.233
14	0.024	0.106	0.106	-0.005	14	0.068	0.027	0.114	-0.139
15	-0.087	-0.215	0.061	-0.056	15	-0.07	-0.251	0.048	0.066
16	0.272	0.331	0.116	0.091	16	0.216	0.019	-0.154	-0.193
17	-0.1	-0.204	0.009	-0.015	17	-0.049	0.128	0.106	-0.086
18	-0.029	0.088	-0.073	-0.068	18	-0.162	0.021	0.016	-0.012
19	-0.148	-0.23	-0.033	0.015	19	-0.071	-0.141	-0.055	-0.039
20	0.241	0.351	-0.022	-0.073	20	0.093	0.1	-0.028	-0.252
21	-0.146	-0.228	0.121	0.175	21	-0.147	-0.052	0.198	0.063
22	-0.032	0.123	-0.052	-0.043	22	0.001	-0.067	-0.109	0.068
23	-0.182	-0.255	-0.146	-0.138	23	0.023	-0.01	-0.123	-0.028
24	0.23	0.421	0.008	0.185	24	-0.027	0.164	-0.033	-0.11

Table-9 : ARIMA (0,0,0)(0,1,1)4 Model For Total Landings

Variable	B	SEB	T-RATIO	APPROX. PROB.
SMA1	0.684382	0.079894	8.566133	0

Table-10 : ARIMA (0,1,1)(2,1,3)4 Model For Bombay duck Landings

Variables	B	SEB	T-RATIO	APPROX. PROB.
MA1	0.858179	0.06184	13.87741	0
SAR1	-1.2155	0.140683	-8.63996	0
SAR2	-0.74923	0.124972	-5.99517	0.00000004
SMA1	-0.57344	0.214718	-2.67064	0.00900013
SMA2	0.482748	0.178485	2.704688	0.00819138
SMA3	0.879716	0.216792	4.057883	0.00010633

Table-11 : ARIMA (0,1,1)(2,1,1)4 Model For Carangid Landings

Variables	B	SEB	T-RATIO	APPROX. PROB.
MA1	0.863698	0.057872	14.92434	0
SAR1	-0.39184	0.1587	-2.46906	0.0154132
SAR2	-0.43452	0.112723	-3.8548	0.00021591
SMA1	0.316095	0.183622	1.721442	0.08856867

Table-12 : ARIMA (0,1,1)(0,1,1)4 Model For Cat fish Landings

Variables	B	SEB	T-RATIO	APPROX. PROB.
MA1	0.750805	0.071667	10.47624	0
SMA1	0.776793	0.077565	10.01476	0

Table-13 : ARIMA (2,1,3)(2,1,1)4 Model For mackerel Landings

Variables	B	SEB	T-RATIO	APPROX. PROB.
AR1	-1.48192	0.055014	-26.9373	0
AR2	-0.96182	0.054399	-17.6808	0
MA1	-0.70569	1.051922	-0.67085	0.50409067
MA2	0.508175	0.333688	1.522902	0.13140981
MA3	0.921609	1.186687	0.776624	0.43948755
SAR1	-0.63001	0.159333	-3.95406	0.00015636
SAR2	-0.50783	0.133654	-3.79956	0.00026833
SMA1	0.247772	0.205649	1.204829	0.23153628

Table-14 : ARIMA (0,1,1)(0,1,4)4 Model For Non-penaeid prawn Landings

Variables	B	SEB	T-RATIO	APPROX. PROB.
MA1	0.832882	0.067834	12.27825	0
SMA1	0.745609	0.107441	6.939681	0
SMA2	0.17223	0.117367	1.467439	0.14574245
SMA3	0.280158	0.125773	2.227494	0.02840794
SMA4	-0.38841	0.112111	-3.46447	0.00081588

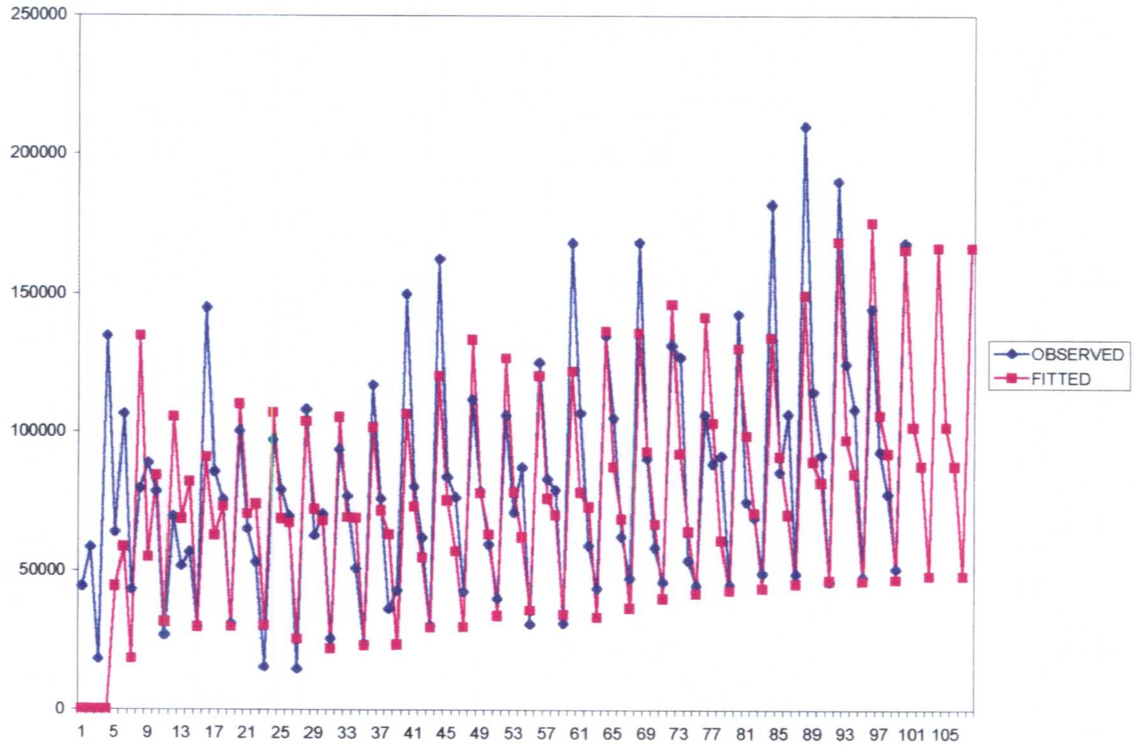

Figure-4

Graph between Fitted values of ARIMA (0,1,1)(0,1,1)4 model (1975-1999) with the observed values (1975-2001)

(Total landings)

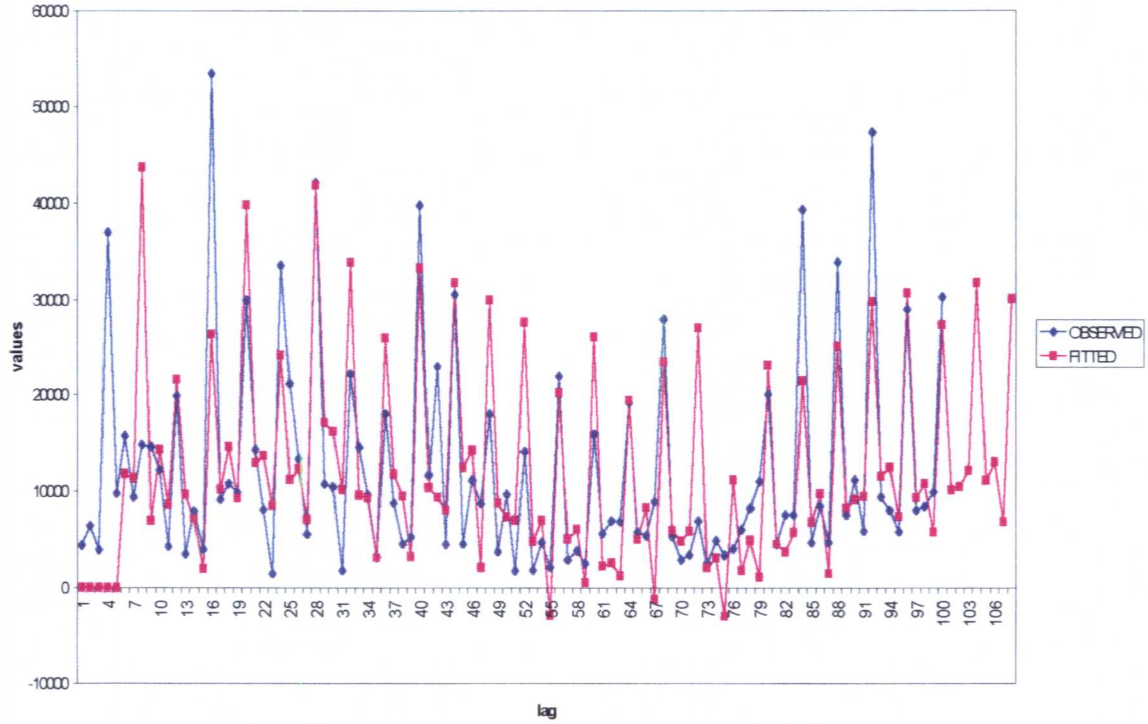

Figure-5

Graph between Fitted values of ARIMA (0,1,1)(2,1,3) model (1975-1999) with the observed values (1975-2001)

(Bombay duck)

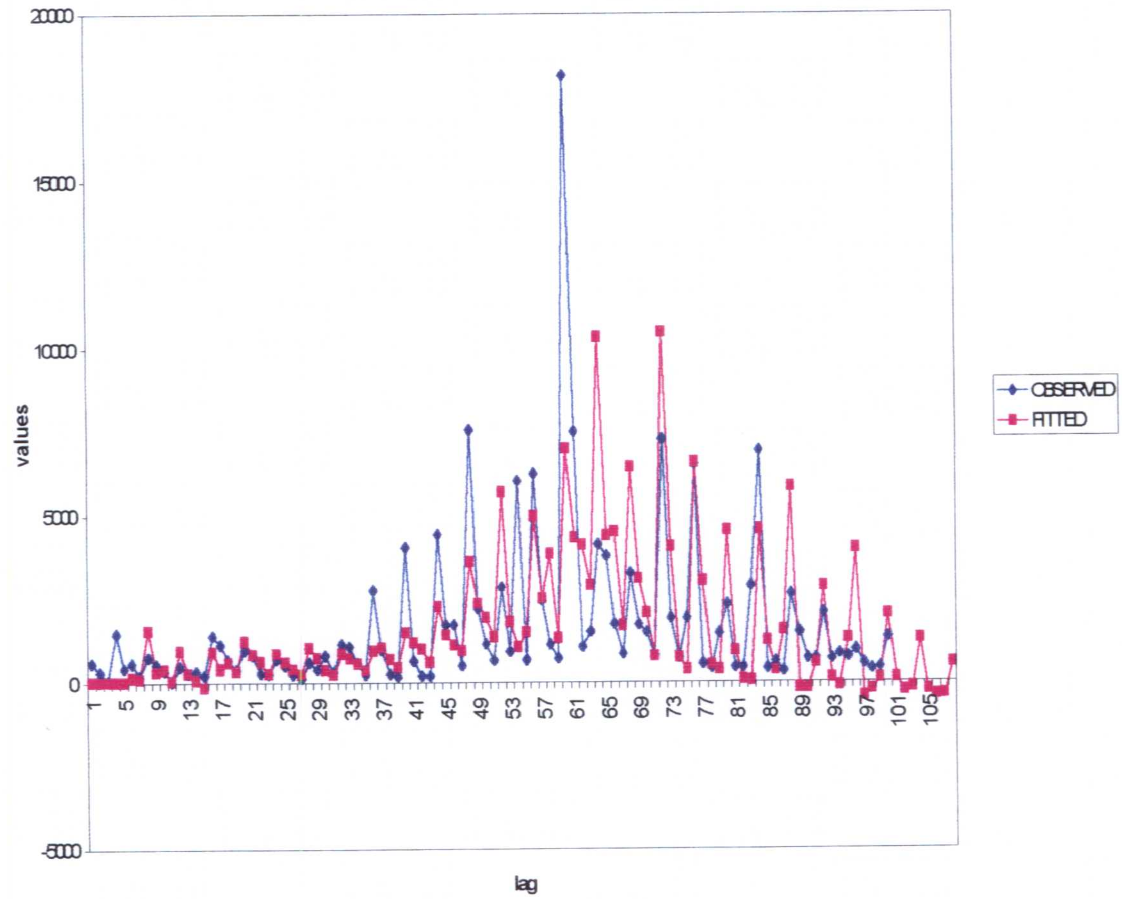

figure-6

Graph between Fitted values of ARIMA (0,1,1)(2,1,1) model (1975-1999) with the observed values (1975-2001)

(Carangids)

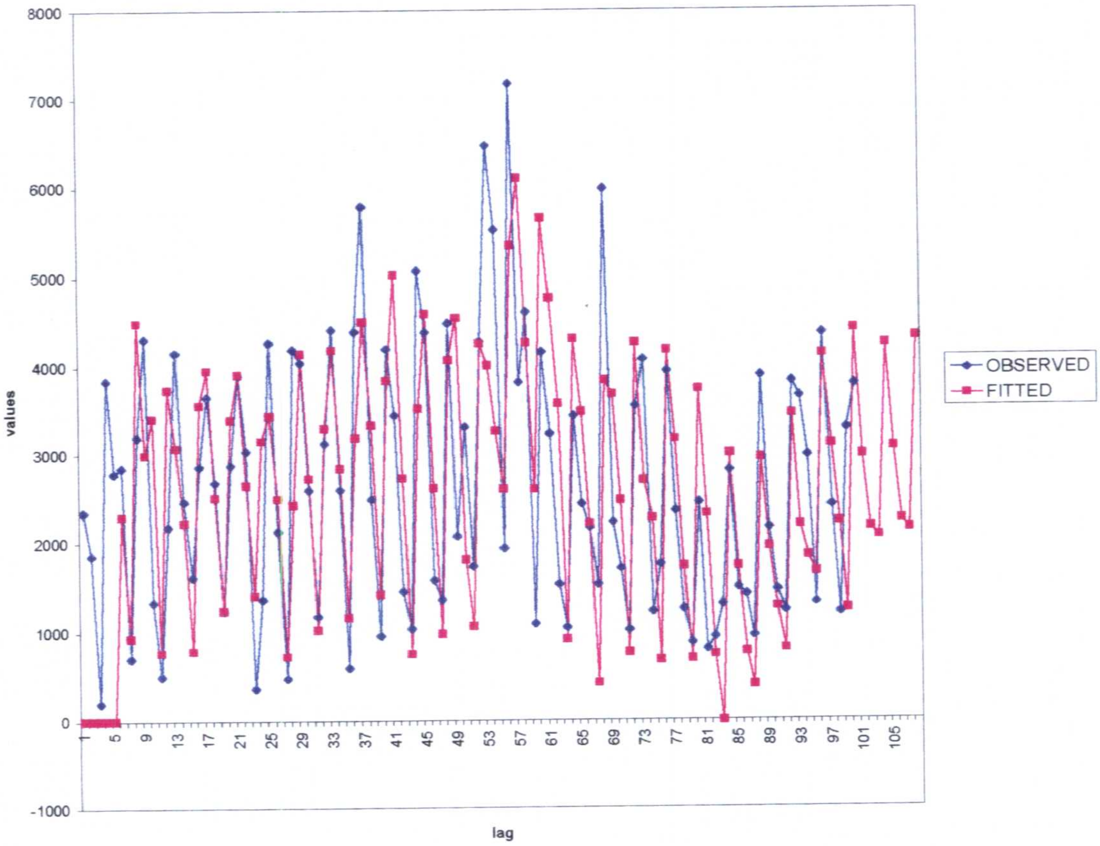

Figure-7

Graph between Fitted values of ARIMA (0,1,1)(0,1,1)4 model (1975-1999) with the observed values (1975-2001)

(Cat fish)

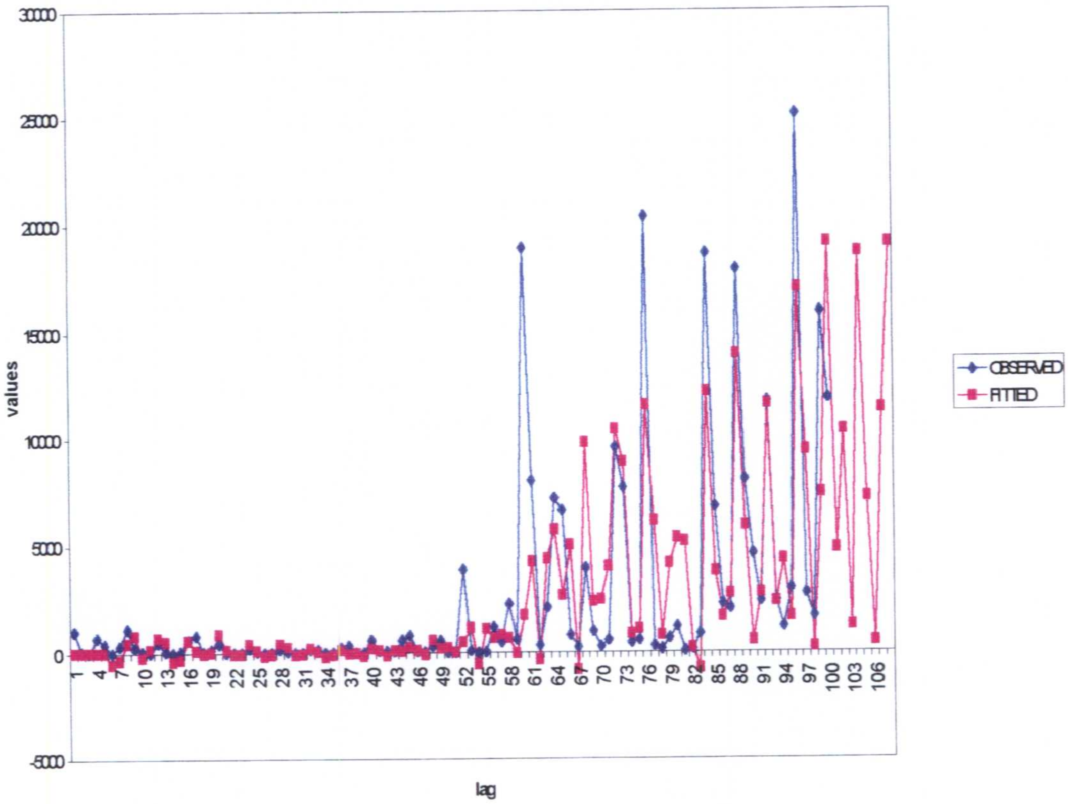

Figure-8

Graph between Fitted values of ARIMA (2,1,3)(2,1,1)4 model (1975-1999) with the observed values (1975-2001)

(Mackerel)

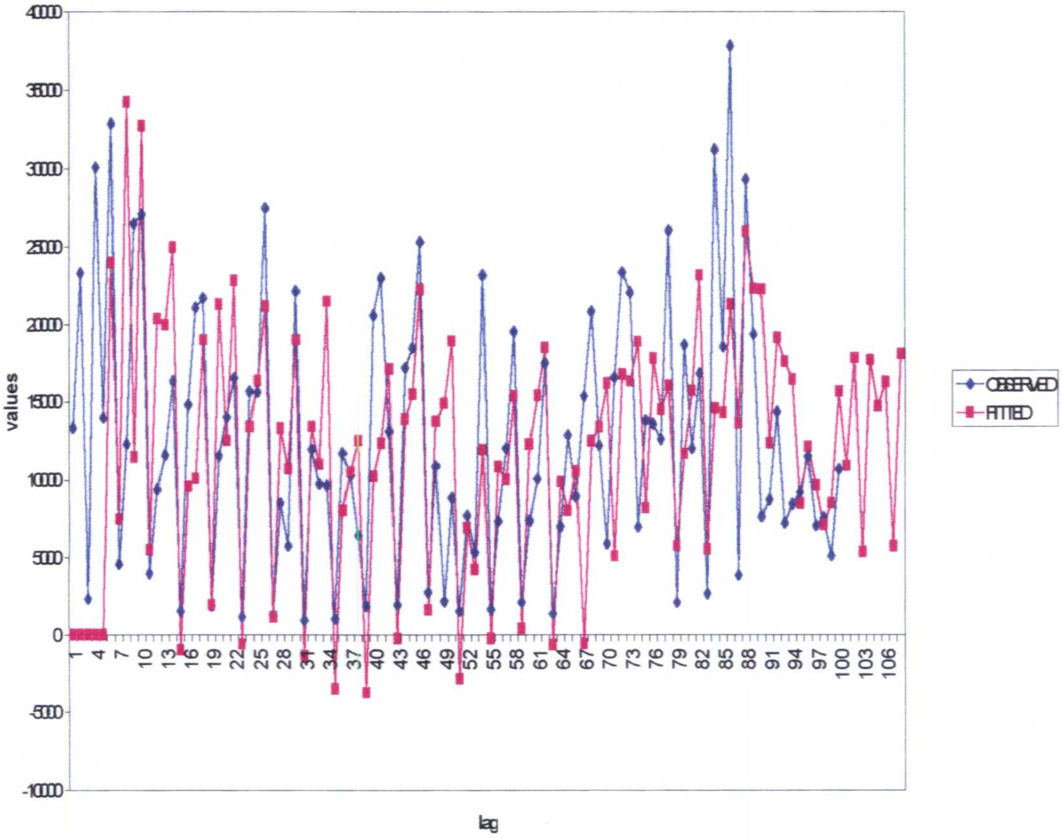

Figure-9

Graph between Fitted values of ARIMA (0,1,1)(0,1,4)4 model (1975-1999) with the observed values (1975-2001)

(Non - penaeid)

Discussion

5. DISCUSSION

Mackerel landings increased considerably during the last two decades. During eighties its average landings were only 3260 tonnes, which rose to 21,196 tonnes in nineties. Compound growth rate was as high as 89.66% for Mackerel in eighties. The species, which was occurring as a stray catch, has emerged as a major resource contributing on an average about 5% to the total marine fish landings of Maharashtra during nineties. Biotic and abiotic factors responsible for this change need to be investigated further. Though average carangid landings remained almost the same during both the decades, there was a negative growth of about 16% during 1990-1999. Cat fishes showed declining trend in nineties as compared to eighties. Non-penaeid prawns though had higher average landings during nineties, growth rate during both the decades were however negative.

Based on the quarterly landing data for the period 1975-1999, forecasting of landings was attempted for the years 2000 and 2001 on quarterly basis. The observed and expected values of total landings, Bombay duck, Carangids, Cat fishes, Mackerel and non-penaeid prawn landings are shown in figure 3-8. It is seen that there is close agreement between observed and expected values. It is also further reflected in lower standard errors, log likely hood, AIC and SBC values.

It is observed that total landings estimated for 1999 were 4,11,594 tonnes against observed value of 3,90,541 tonnes indicating about 5.4% error. Similarly the estimated landings of Bombay duck landings and catfish had an error of 6% and 2.5% respectively for 1999. About 12% error was noticed in the case of estimated landings of Mackerel for 1999. The estimated landings based on the identified models for non-penaeid prawns and carangids showed larger variation between observed and estimated values with an error of 34% and 46% respectively. Hence further refining of models for non-penaeid prawns and carangids is required. However the

ARIMA models developed in the present study can be usefully employed in forecasting of total landings as well as landings of Bombay duck and cat fishes.

The major objective of any forecasting is to plan systematically for any infrastructure requirement, human resource development, and regulation of undesired factors so that the resultant development is sustainable and productive. Forecasting of marine fish production is very much essential for proper planning. Fluctuation in marine fish production affects the processing industry, export earnings, employment and income to fishermen community, marketing and cost of marine fish products and advance information about future catch will help in proper planning, storage, and distribution. The results of the present study are thus expected to go a long way in improving management of marine fisheries of Maharashtra.

Summary

SUMMARY

The data for the present study were obtained from reports of Central Marine Fisheries Research Institute, Kochi and Department of Fisheries, Government of Maharashtra. The annual landings during the last two decades 1980-1989 and 1990-1999 were analyzed for estimation of compound growth rates. The quarterly total landings and landings of Bombay duck, Carangids, Cat fishes, Mackerel and Non-penaid prawns during the period 1975-1999 were used for fitting ARIMA models. Auto correlation and partial auto correlation were worked out for identifying the seasonality or otherwise of the time series. Akaike Information Criterion (AIC) and Schewatz Bayesean information Criterion were used for the estimation of the order of the model. An algorithm using "trends" module in SPSS software was used for estimation of model parameters.

For realizations, which contained both seasonal and non-seasonal patterns, the following general ARIMA model is used:

$$\phi(B)\ \varphi(B^s)\ \nabla^d \nabla_s^d z_t = \theta(B)\Theta(B^s) \text{ --------------------- } (3.16)$$

$\phi(B)$ is the non-seasonal AR operator,

$\varphi(B^s)$ is the seasonal AR operator,

$\theta(B)$ is the non-seasonal MA operator,

$\Theta(B^s)$ is the seasonal MA operator and

$\nabla^d \nabla_s^d$ are differencing operators

The general ARIMA model is specified as ARIMA (p,d,q)(P,D,Q)4. That is the order of auto regression is p, order of differencing is d, order of moving average term is q, order of seasonal auto regression is P, order of seasonal differencing is D, order of seasonal moving average term is Q and seasonality is 4.

Mackerel landings increased considerably during the last two decades. During eighties its average landings were only 3,2250 tonnes which rose to 21,196 tonnes in nineties. Compound growth rate was as high as 89.66%. In eighties the species, which was occurring as a stray catch, has emerged as a major resource contributing on an average about 5% to the total marine fish landings of Maharashtra during nineties. Biotic and abiotic factors responsible for this change need to be investigated further. Though average carangid landings remained almost the same during both the decades, there was a negative growth of about 16% during 1990-1999. Cat fishes showed declining trend in nineties as compared to eighties. Non-penaeids though had higher average landings during nineties, growth rate during both the decades were however negative.

The models identified in the present study are ARIMA (0,0,0)(0,1,1) for total landings, ARIMA (0,1,1)(2,1,3) for Bombay duck, ARIMA (0,1,1)(2,1,1) for carangid landings, ARIMA (0,1,1)(0,1,1) for catfish, ARIMA (2,1,3)(2,1,1) for Mackerel, and ARIMA (0,1,1)(0,1,4) for non-penaeid prawns. T-ratio showed that the fitted models are adequate to explain the data. Fitted models were used to forecast landings for the next two years 2000 and 2001on quarterly basis.

It is observed that total landings estimated for 1999 were 4,11,594 tonnes against observed value of 3,90,541 tonnes indicating about 5.4% error. Similarly the estimated landings of Bombay duck landings and catfish had an error of 6% and 2.5% respectively for 1999. About 12% error was noticed in the case of estimated landings of Mackerel for 1999. The estimated landings based on the identified models for non-penaeid prawns and carangids showed larger variation between observed and estimated values with an error of 34% and 46% respectively. Hence further refining of models for non-penaeid prawns and carangids is required. However the ARIMA models developed in the present study can be usefully employed in forecasting of total landings as well as landings of Bombay duck and cat fishes. Advance information about future landings will help in proper planning, storage and distribution. The results of the present study are thus expected to go a long way in improving management of marine fisheries of Maharashtra.

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